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(54) **SIDE STORAGE PODS, EQUIPMENT FRONT END MODULES, AND METHODS FOR OPERATING EFEMS**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

9,105,673 B2 * 8/2015 Babbs H01L 21/67213
9,524,892 B2 * 12/2016 Rebstock H01L 21/67766
(Continued)

FOREIGN PATENT DOCUMENTS

EP 0497281 A2 8/1992
JP 2017-011150 A 1/2017
(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion of International Application No. PCT/US2019/057651 dated Feb. 12, 2020.

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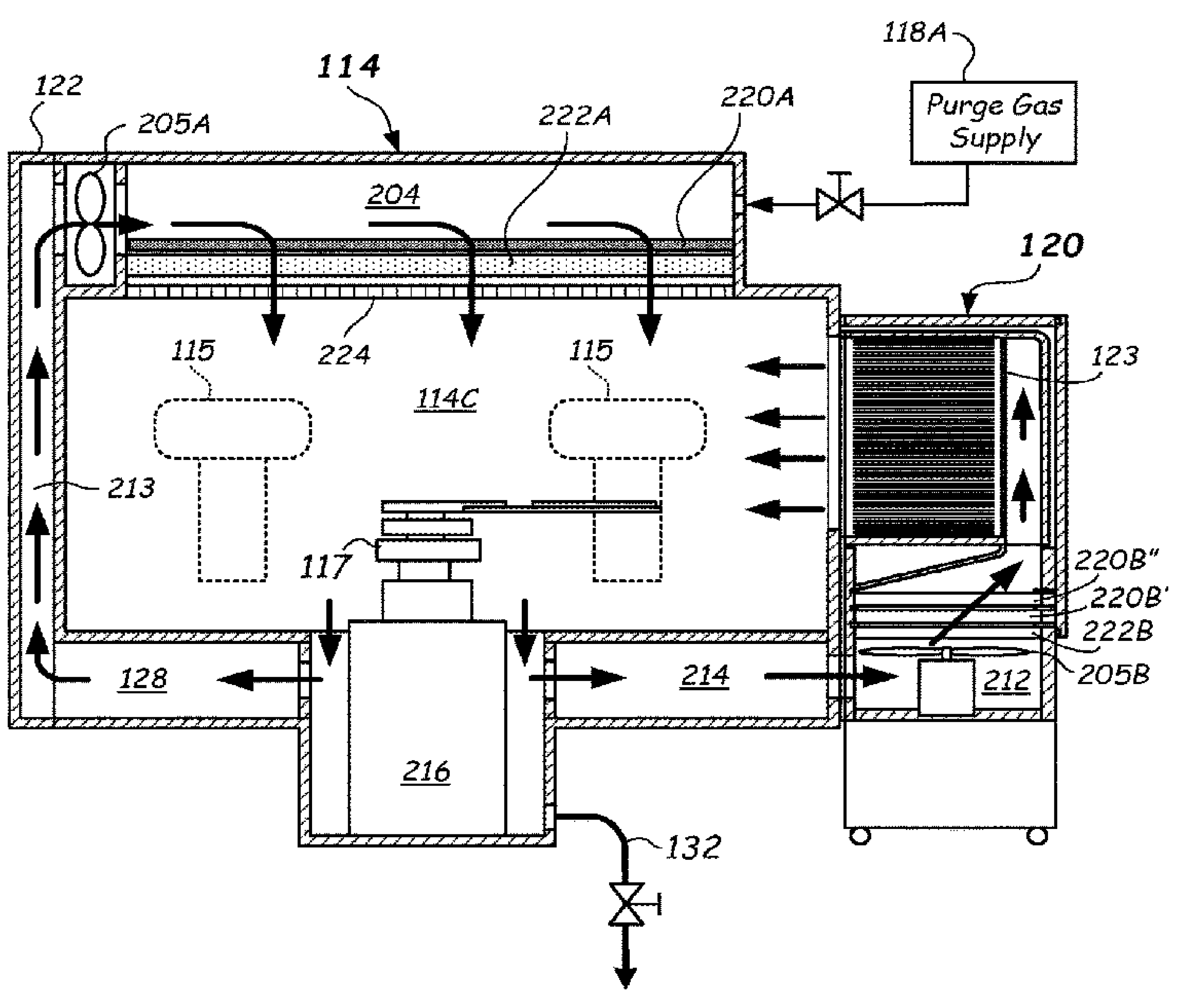
(57) **ABSTRACT**

Electronic device processing systems including an equipment front end module with at least one side storage pod are described. The side storage pod has a side storage container and a container plenum. A fan draws purge gas from the equipment front end module chamber into the container plenum where the purge gas is directed into the side storage container to pass over substrates stored therein and is then exhausted back into the equipment front end module chamber. Methods and systems are also disclosed.

21 Claims, 5 Drawing Sheets



(51) **Int. Cl.**
H01L 21/677 (2006.01)
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(52) **U.S. Cl.**
CPC .. ***H01L 21/67769*** (2013.01); *H01L 21/67766* (2013.01); *H01L 21/67772* (2013.01); *H01L 21/67775* (2013.01); *H01L 21/67778* (2013.01); *H01L 21/68707* (2013.01)

(58) **Field of Classification Search**
CPC H01L 21/67766; H01L 21/68707; H01L 21/67775; H01L 21/67778; H01L 21/67772
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,192,765	B2 *	1/2019	Koshti	H01L 21/67772
10,359,743	B2 *	7/2019	Rice	H01L 21/67775
10,388,547	B2 *	8/2019	Holeyannavar	H01L 21/67379
10,522,379	B2 *	12/2019	Kong	H01L 21/67393
10,566,216	B2 *	2/2020	Senn	H01L 21/67739
10,763,134	B2 *	9/2020	Rice	H01L 21/67769
10,777,437	B2 *	9/2020	Fukasawa	H01L 21/67017
10,847,390	B2 *	11/2020	Holeyannavar	H01L 21/6719
2011/0114129	A1 *	5/2011	Kishkovich	H01L 21/67017 134/22.1
2015/0101482	A1 *	4/2015	Chou	B01D 46/442 95/12
2015/0170945	A1 *	6/2015	Segawa	H01L 21/67772 414/217
2015/0228518	A1 *	8/2015	Hyon	H01L 21/67389 156/345.1
2016/0118282	A1 *	4/2016	Maraschin	H01L 21/67393 414/222.07
2016/0284580	A1 *	9/2016	Woo	H01L 21/67393
2017/0011942	A1 *	1/2017	Woo	H01L 21/67724
2017/0170042	A1	6/2017	Okabe et al.	
2018/0114710	A1 *	4/2018	Jeong	H01L 21/673
2018/0124960	A1 *	5/2018	Vincent	H01L 21/67201
2018/0286726	A1 *	10/2018	Rebstock	H01L 21/67389
2018/0374725	A1 *	12/2018	Holeyannavar	H01L 21/67201
2018/0374733	A1 *	12/2018	Pannese	H01L 21/67769
2020/0135499	A1 *	4/2020	Pannese	B01D 46/0039
2020/0135520	A1 *	4/2020	Reuter	H01L 21/67017
2020/0135521	A1 *	4/2020	Reuter	H01L 21/67389
2020/0135523	A1 *	4/2020	Reuter	H01L 21/67389
2020/0350193	A1 *	11/2020	Garssen	H01L 21/67769

FOREIGN PATENT DOCUMENTS

KR	101758214 B1	7/2017
KR	10-2018-0074276 A	7/2018

* cited by examiner

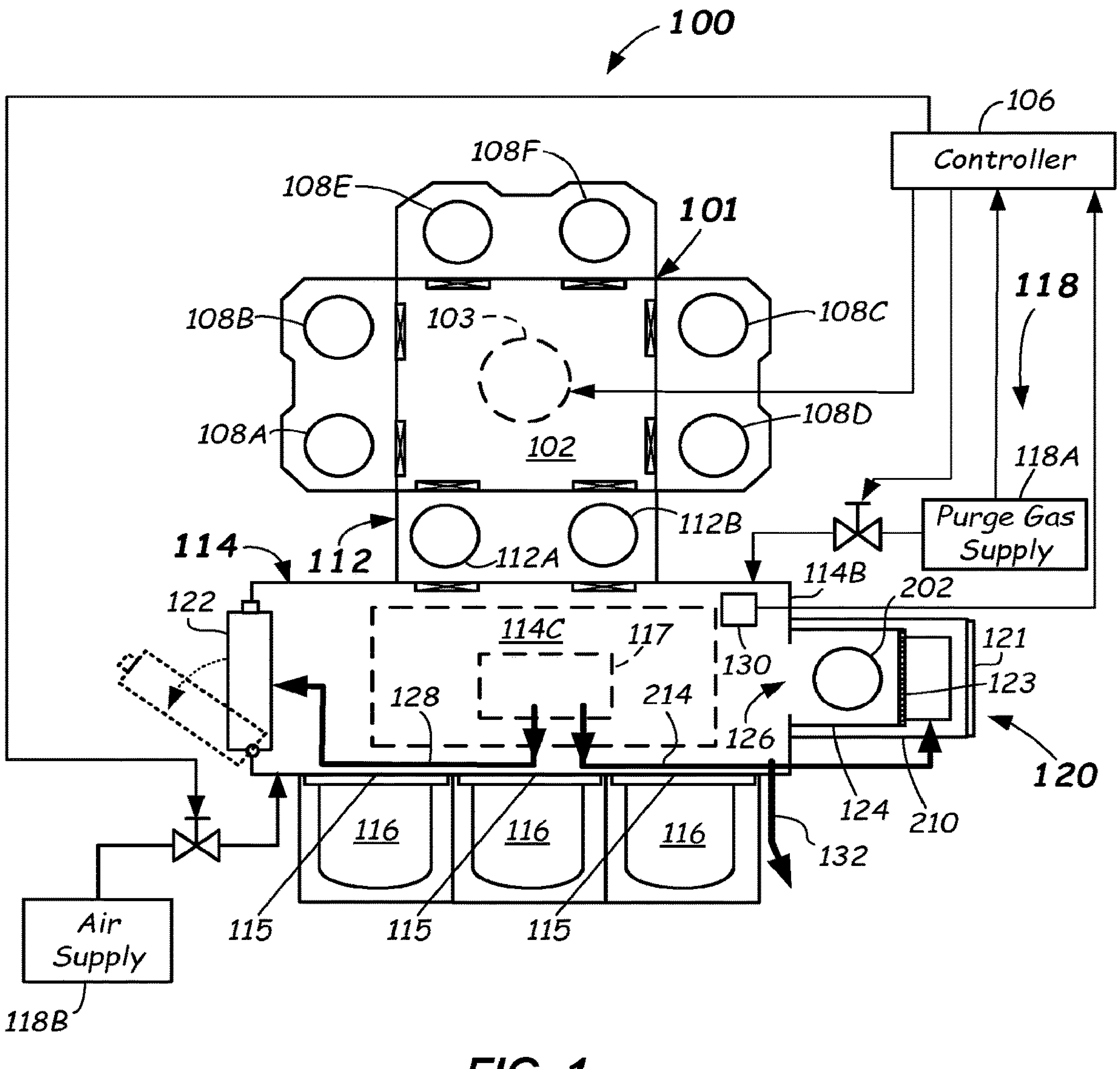
100
106
Controller
108F
108E
101
118
108B
103
108C
108A
102
108D
118A
Purge Gas Supply
114
112
112B
112A
114B
202
122
114C
117
121
130
123
128
214
126
120
116
116
116
124
210
132
115
115
115
Air Supply
118B

FIG. 1

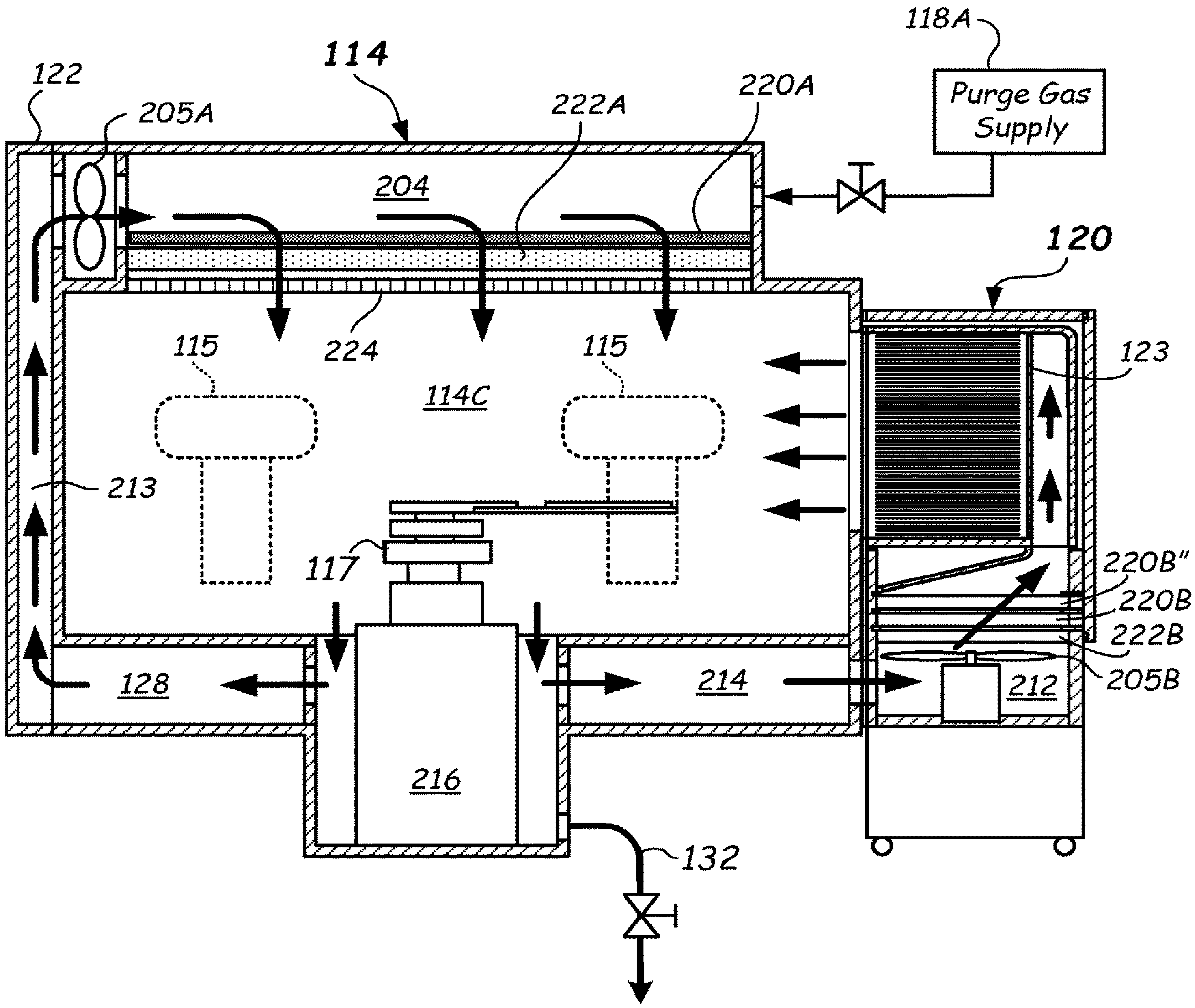
118A
Purge Gas Supply
114
122
205A
222A
220A
204
120
123
115
224
115
114C
213
117
220B"
220B'
222B
128
214
212
205B
216
132

FIG. 2

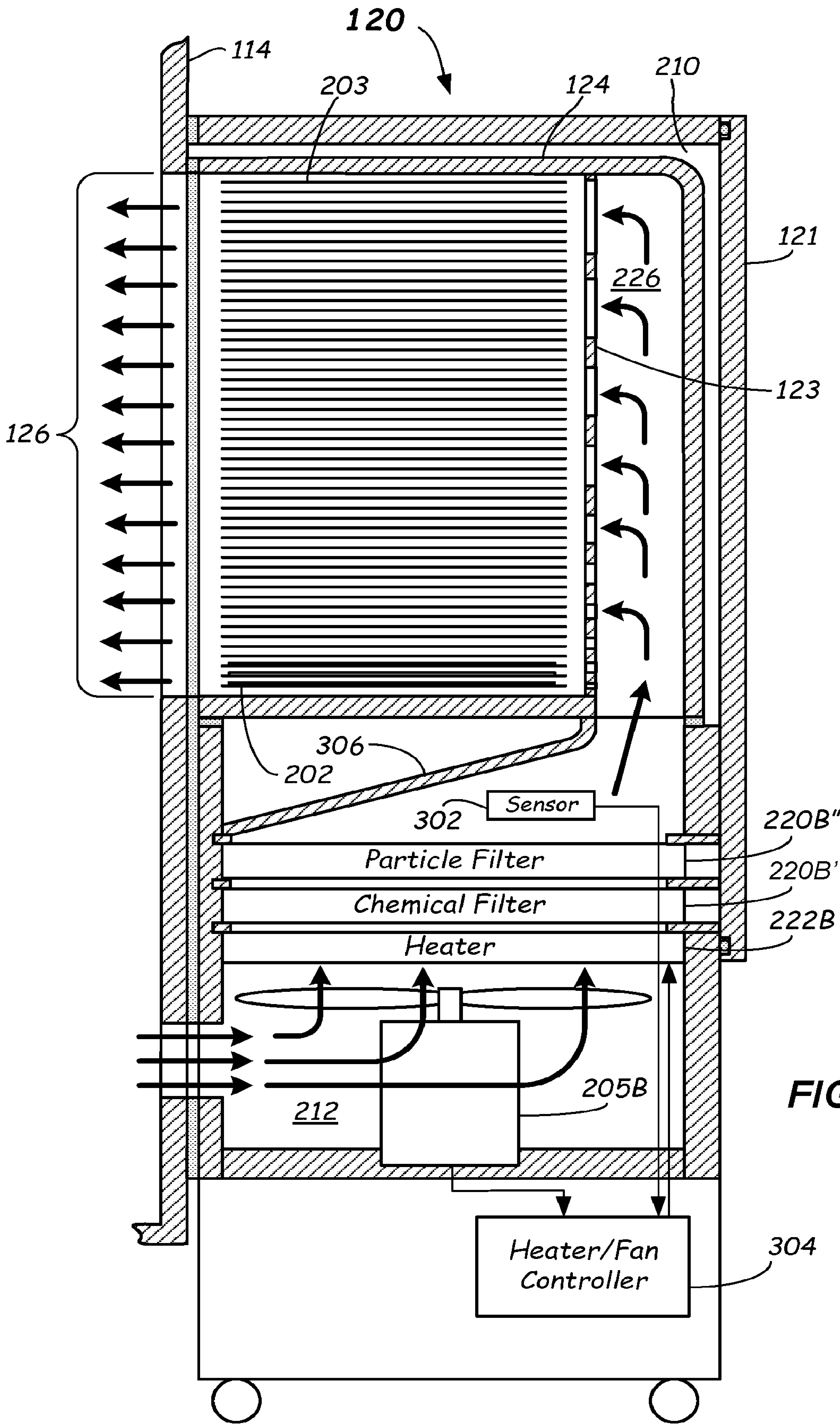
120
114
203
124
210
121
226
123
126
306
202
Sensor
302
220B"
Particle Filter
220B'
Chemical Filter
222B
Heater
205B
212
Heater/Fan
Controller
304

FIG. 3

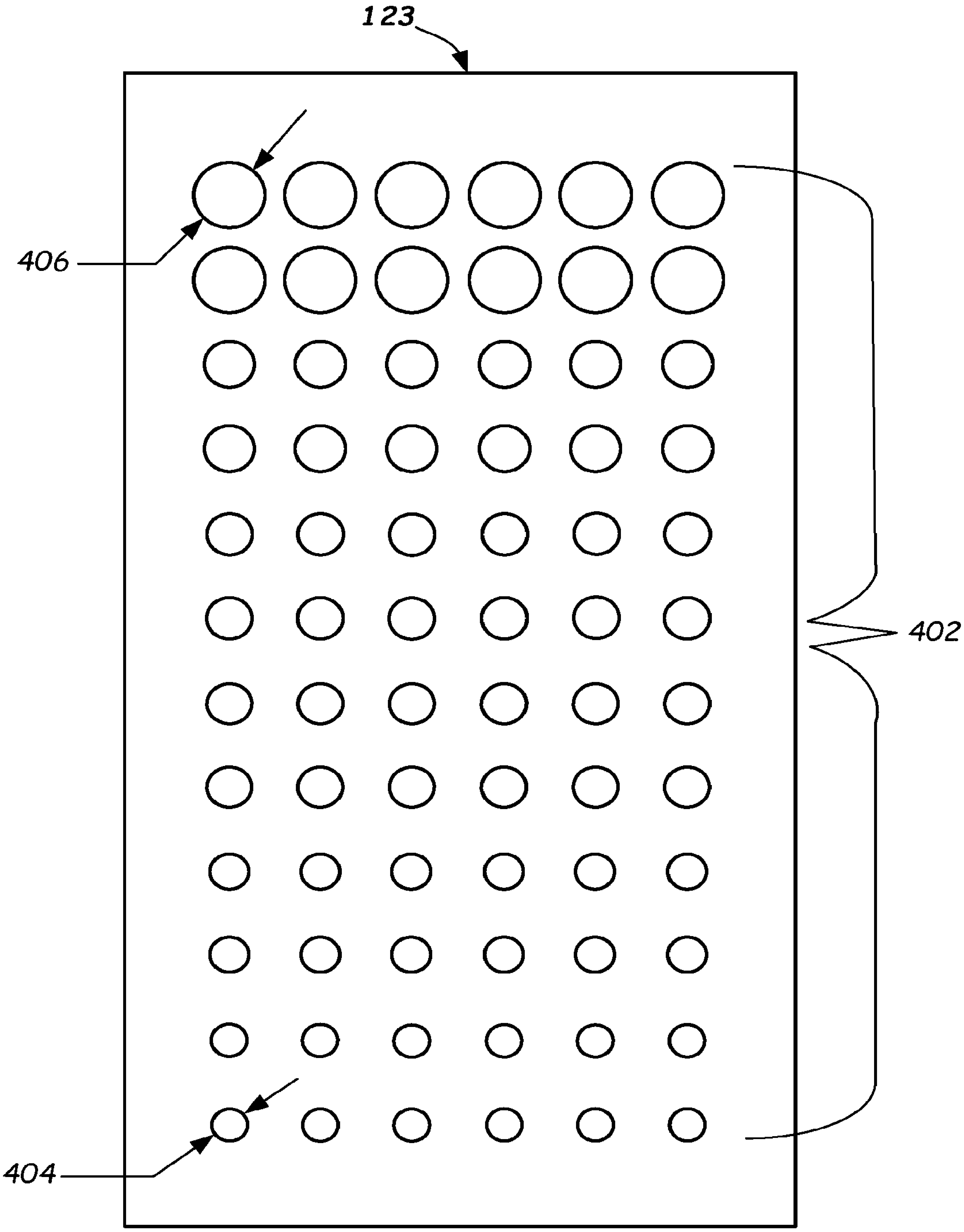

FIG. 4

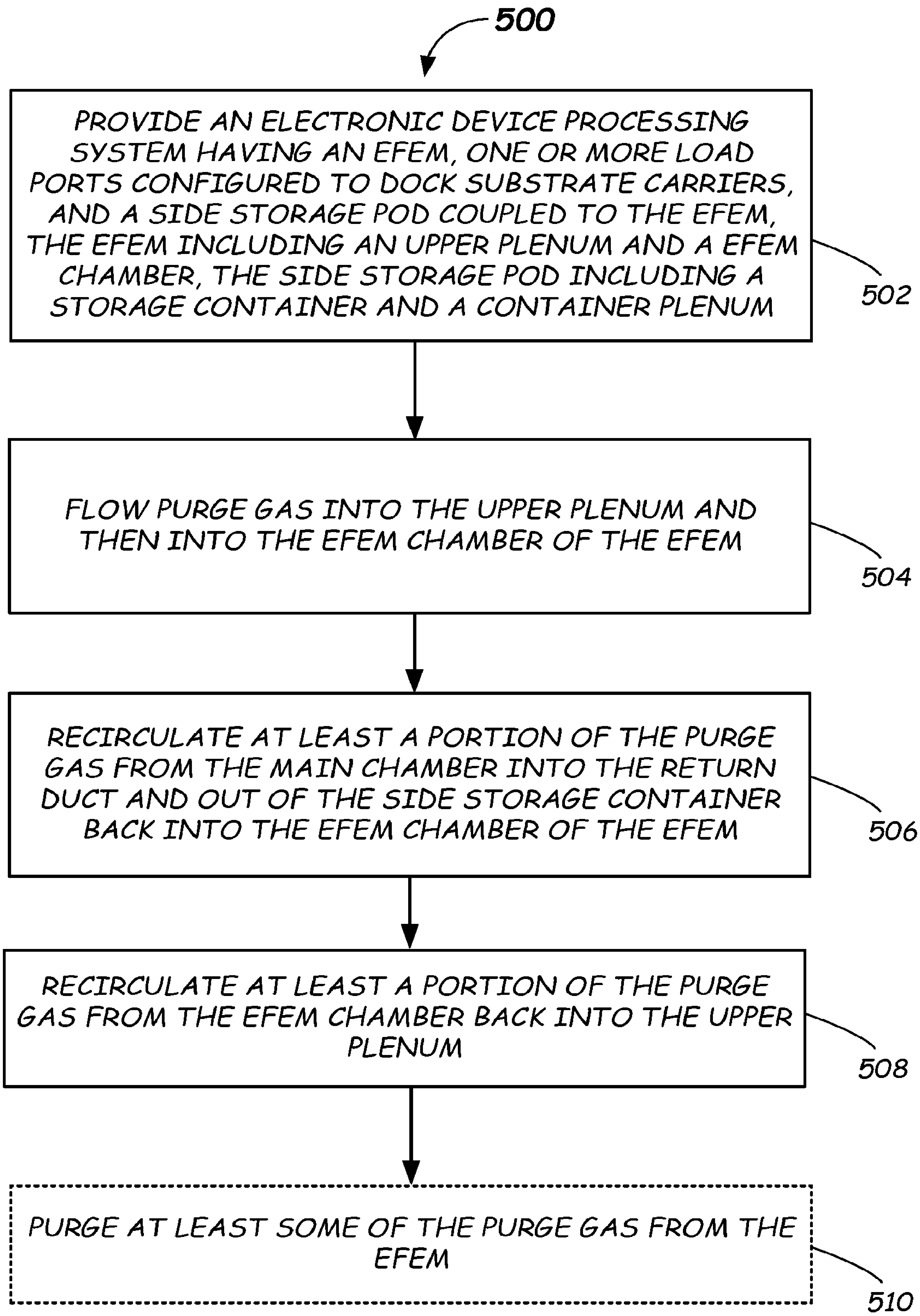
500
PROVIDE AN ELECTRONIC DEVICE PROCESSING SYSTEM HAVING AN EFEM, ONE OR MORE LOAD PORTS CONFIGURED TO DOCK SUBSTRATE CARRIERS, AND A SIDE STORAGE POD COUPLED TO THE EFEM, THE EFEM INCLUDING AN UPPER PLENUM AND A EFEM CHAMBER, THE SIDE STORAGE POD INCLUDING A STORAGE CONTAINER AND A CONTAINER PLENUM
502
FLOW PURGE GAS INTO THE UPPER PLENUM AND THEN INTO THE EFEM CHAMBER OF THE EFEM
504
RECIRCULATE AT LEAST A PORTION OF THE PURGE GAS FROM THE MAIN CHAMBER INTO THE RETURN DUCT AND OUT OF THE SIDE STORAGE CONTAINER BACK INTO THE EFEM CHAMBER OF THE EFEM
506
RECIRCULATE AT LEAST A PORTION OF THE PURGE GAS FROM THE EFEM CHAMBER BACK INTO THE UPPER PLENUM
508
PURGE AT LEAST SOME OF THE PURGE GAS FROM THE EFEM
510

FIG. 5

SIDE STORAGE PODS, EQUIPMENT FRONT END MODULES, AND METHODS FOR OPERATING EFEMS

RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 62/751,522, filed Oct. 26, 2018, which is incorporated herein, in its entirety, by this reference.

FIELD

The present disclosure relates to electronic device manufacturing, and more specifically to equipment front end modules, side storage pods, and methods for operating EFEMs.

BACKGROUND

Electronic device manufacturing systems may include multiple process chambers arranged around a mainframe housing having a transfer chamber and one or more load lock chambers configured to pass substrates into the transfer chamber.

Processing of substrates in electronic device (e.g., semiconductor component) manufacturing may be carried out in multiple tools, where the substrates travel between the tools in substrate carriers (e.g., front end unified pods or FOUPs). Exposure of the substrates to certain environmental conditions during processing may degrade the substrates. For example, exposure to humidity during processing of substrates may form acids on the substrates, which may degrade or destroy components fabricated onto the substrates.

Accordingly, improved systems, apparatus, and methods for controlling the environmental conditions of substrates during processing are desired.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings, described below, are for illustrative purposes and are not necessarily drawn to scale. The drawings are not intended to limit the scope of the disclosure in any way.

FIG. **1** illustrates a schematic top view of an electronic device processing system including a side storage pod according to one or more embodiments of the disclosure.

FIG. **2** illustrates a side, cross-sectional, elevation view of an equipment front end module (hereinafter "EFEM") including a side storage pod coupled to the EFEM body according to one or more embodiments of the disclosure.

FIG. **3** illustrates a side, cross-sectional, elevation view of a side storage pod according to one or more embodiments of the disclosure.

FIG. **4** illustrates a supply baffle of a side storage pod according to one or more embodiments of the disclosure.

FIG. **5** illustrates a flowchart depicting an example method of operating an equipment front end module according to one or more embodiments of the disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to the example embodiments of this disclosure, which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts throughout the several views.

Features of the various embodiments described herein may be combined with each other, unless specifically noted otherwise.

Electronic device manufacturing may involve exposing substrates to different chemicals during a plurality of process. In between different processes being applied to the substrates, the substrates may undergo outgassing. Some processes applied to the substrate may cause the substrate to outgas corrosive chemicals, such as fluorine, bromine, and chlorine. If these chemicals or compounds thereof are not removed from the substrates, certain defects may be caused in the substrates.

According to one or more embodiments of the disclosure, electronic device processing systems, side storage pods, and methods adapted to improve substrate processing are provided. The systems, side storage pods, and methods described herein may provide efficiency and/or processing improvements in the processing of substrates by controlling environmental exposure of the substrates, and, in particular, conditions within one or more side storage pods coupled to an equipment front end module (hereinafter "EFEM"). One or more side storage containers may be configured to be receivable within a side storage pod and may include substrate holders (e.g., shelves) that receive and support substrates, such as during idle periods before and/or after processes are applied to the substrates.

Gas may flow from a side storage container where it flows past substrates located therein into the EFEM. The gas may be exhausted from the base of the EFEM chamber and, in some embodiments, passed through a chemical filter. Some of the filtered gas may then be recirculated back into the EFEM and/or the side storage container. In some embodiments, the recirculation path of the gas may pass through an access door to the EFEM, which may minimize the space occupied by the recirculation path. The gas recirculated into the EFEM chamber can be substantially is free of certain gasses filtered by the chemical filter. In addition, the substrates are exposed to the purge gas within the EFEM chamber and side storage pod, which may have certain environmental conditions, such as being relatively dry and/or having relatively low O_2 levels.

Further details of example embodiments of side storage pods, systems (e.g., EFEMs) including a side storage pod, and methods of operating EFEMs are described with reference to FIGS. **1**-**5** herein.

FIG. **1** illustrates a schematic diagram of an example embodiment of an electronic device processing system **100** according to one or more embodiments of the present disclosure. The electronic device processing system **100** may include a mainframe housing **101** having housing walls defining a transfer chamber **102**. A transfer robot **103** (shown as a dotted circle) may be at least partially housed within the transfer chamber **102**. The transfer robot **103** may be configured to place and extract substrates to and from destinations via operation of arms (not shown) of the transfer robot **103**. Substrates as used herein may mean articles used to make electronic devices or circuit components, such as semiconductor wafers, silicon-containing wafers, patterned wafers, glass plates, or the like.

The motion of the various arm components of the transfer robot **103** may be controlled by suitable commands to a drive assembly (not shown) containing a plurality of drive motors of the transfer robot **103** as commanded from a controller **106**. Signals from the controller **106** may cause motion of the various components of the transfer robot **103**.

Suitable feedback mechanisms may be provided for one or more of the components by various sensors, such as position encoders, or the like.

The transfer chamber **102** in the depicted embodiment may be square or slightly rectangular in shape and may include a plurality of facets on the walls of the transfer chamber **102**. The transfer robot **103** may be adept at transferring and/or retracting dual substrates concurrently into the chamber sets. The facets may be planar and entryways into the chamber sets may lie along the respective facets. However, other suitable shapes of the mainframe housing **101** and numbers of facets and processing chambers are possible.

The destinations for the transfer robot **103** may be a first process chamber set **108**A, **108**B, coupled to a facet of the transfer chamber **102** and which may be configured and operable to carry out a process on the substrates delivered thereto. The process may be any suitable process such as plasma vapor deposition (PVD) or chemical vapor deposition (CVD), etch, annealing, pre-clean, metal or metal oxide removal, or the like. Other processes may be carried out on substrates therein.

The destinations for the transfer robot **103** may also be a second process chamber set **108**C, **108**D that may be opposed from the first process chamber set **108**A, **108**B. The second process chamber set **108**C, **108**D may be coupled to a second facet of the transfer chamber **102** and may be configured to carry out any suitable process on the substrates, such as any of the processes mentioned above. Likewise, the destinations for the transfer robot **103** may also be a third process chamber set **108**E, **108**F that may be opposed from a load lock apparatus **112** coupled to a third facet of the transfer chamber. The third process chamber set **108**E, **108**F may be configured to carry out any suitable process on the substrates, such as any of the processes mentioned above.

Substrates may be received into the transfer chamber **102** from an EFEM **114**, and also exit the transfer chamber **102**, to the EFEM **114**, through the load lock apparatus **112** that is coupled to a surface (e.g., a rear wall) of the EFEM **114**. The load lock apparatus **112** may include one or more load lock chambers (e.g., load lock chambers **112**A, **112**B, for example). Load lock chambers **112**A, **112**B included in the load lock apparatus **112** may be single wafer load lock (SWLL) chambers, multi-wafer chambers, or combinations thereof.

The EFEM **114** may include an enclosure having side walls (such as a front wall, rear wall, side walls, a top wall, and a bottom wall, for example) forming an EFEM chamber **114**C. One or more load ports **115** may be provided on a wall (e.g., a front) of the EFEM **114** and may be configured to receive and dock one or more substrate carriers **116** (e.g., FOUPs) thereat. Three substrate carriers **116** are shown, but more or less numbers of substrate carriers **116** may be docked with the EFEM **114**.

EFEM **114** may include a suitable load/unload EFEM robot **117** (shown dotted) of conventional construction within the EFEM chamber **114**C thereof. The EFEM robot **117** may be configured and operational, once a door of a substrate carrier **116** is opened, to extract substrates from the substrate carrier **116** and feed the substrates through the EFEM chamber **114**C and into the one or more load lock chambers **112**A, **112**B of the load lock apparatus **112**.

The EFEM robot **117** may be configured and operational, once the door of a substrate carrier **116** is opened, to extract substrates from the substrate carrier **116** and feed the substrates into a side storage pod **120** while they sit idle awaiting processing. The side storage pod **120** may be coupled to a side wall of the EFEM body **114**B. The EFEM robot **117** may further be configured to extract substrates from and load substrates into the side storage pod **120** prior to and after processing in one or more of the process chambers **108**A-**108**F. In some embodiments, the load/unload EFEM robot **117** is a high-Z robot configured to access substrates stacked greater than 26 high, or even 52 high or higher, in the side storage pod **120**. The side storage pod **120** can include maintenance doors **121** to allow operators to access the interior of the side storage pod **120** when necessary (e.g., during an error condition or maintenance/cleaning).

In the depicted embodiment, the EFEM chamber **114**C may be provided with environmental controls providing an environmentally-controlled atmosphere therein. In particular, an environmental control system **118** may be coupled to the EFEM **114** and may be operational to monitor and/or control environmental conditions within the EFEM chamber **114**C. In some embodiments, and at certain times, the EFEM chamber **114**C may receive a purge gas (e.g., an inert and/or non-reactive gas) therein, such as argon (Ar), nitrogen (N_2), or helium (He), from a purge gas supply **118**A. In other embodiments, or at other times, air (e.g., dry filtered air) may be provided from an air supply **118**B. The environmental conditions within the EFEM chamber **114**C may be present in the interiors of side storage containers located within and as part of the side storage pod **120**. In some embodiments, the side storage pod **120** may have substrate holders located therein to receive substrates **202**.

Although not shown in FIG. **1**, in some embodiments, the purge gas supply **118**A and/or the air supply **118**B may be coupled to the side storage pod **120** to optionally supply gas/air directly to the side storage pod **120**.

In more detail, the environmental control system **118** may control at least one or more of: 1) relative humidity (RH), 2) temperature (T), 3) an amount of O_2, and/or 4) an amount of purge gas, within the EFEM chamber **114**C. Other environmental conditions of the EFEM **114** may be monitored and/or controlled, such as gas flow rate into the EFEM chamber **114**C, or pressure in the EFEM chamber **114**C, or both.

In some embodiments, the environmental control system **118** includes the controller **106**. Controller **106** may include a suitable processor (e.g., a microprocessor), memory, and electronic components for receiving inputs from various sensors and controlling one or more valves to control the environmental conditions within the EFEM chamber **114**C. Environmental control system **118** may, in one or more embodiments monitor relative humidity (RH) by sensing RH in the EFEM **114** with an environmental monitor **130**. Any suitable type of environmental monitor that measures relative humidity may be used, such as a capacitive-type sensor. The RH may be lowered by flow of a suitable amount of the purge gas from the purge gas supply **118**A of the environmental control system **118** into the EFEM chamber **114**C. As described herein, the inert and/or non-reactive gas from the purge gas supply **118**A may be argon, N_2, helium, another non-reactive gas, or mixtures thereof. In some embodiments, compressed bulk inert gases having low H_2O levels (e.g., purity≥99.9995%, $H_2O \geq 5$ ppm) may be used as the inert gas supply **118**A in the environmental control system **118**, for example. Other H_2O levels may be used.

In another aspect, the environmental monitor **130** may measure a plurality of environmental conditions. For example, in some embodiments, the environmental monitor **130** may measure the relative humidity value as discussed above. In one or more embodiments, the pre-defined reference relative humidity value may be less than 1000 ppm moisture, less than 500 ppm moisture, or even less than 100 ppm moisture, depending upon the level of moisture that is tolerable for the particular process being carried out in the electronic device processing system **100** or particular substrates exposed to the environment of the EFEM **114**.

The environmental monitor **130** may also measure a level of oxygen (O_2) within the EFEM **114**. In some embodiments, a control signal from the controller **106** to the environmental control system **118** initiating a flow of a suitable amount of an inert gas from the inert gas supply **118**A into the EFEM chamber **114**C may take place to control the level of oxygen (O_2) to below a threshold O_2 value. In one or more embodiments, the threshold O_2 value may be less than 50 ppm, less than 10 ppm, or even less than 5 ppm, depending upon the level of O_2 that is tolerable (not affecting quality) for the particular process being carried out in the electronic device processing system **100** or particular substrates exposed to the environment of the EFEM **114**. In some embodiments, the environmental monitor **130** may sense the level of oxygen in the EFEM chamber **114**C to ensure it is above a safe threshold level to allow entry into the EFEM chamber **114**C.

The environmental monitor **130** may also measure the absolute or relative pressure within the EFEM **114**. In some embodiments, the controller **106** may control the amount of flow of the purge gas from the purge gas supply **118**A into the EFEM chamber **114**C to control the pressure in the EFEM chamber **114**C.

In some embodiments, the environmental control system **118** of the electronic device processing system **100** may include an air supply **118**B coupled to the EFEM **114**. The air supply **118**B may be coupled by suitable conduits and one or more valves to the EFEM **114**. Air may be provided to the EFEM prior to maintenance or before an operator enters the EFEM chamber **114**C.

In the depicted embodiments herein, the controller **106** may be an overall system controller including a processor (e.g., a microprocessor), memory, and peripheral components adapted to receive control inputs (e.g., relative humidity and/or oxygen) from the environmental monitor **130** and execute a closed loop or other suitable control scheme. In some embodiments, the control scheme may change a flow rate of the purge gas being introduced into the EFEM chamber **114**C to achieve a predetermined environmental condition therein. In some other embodiments, the control scheme may determine when to transfer substrates into the EFEM **114**.

As will be described in detail below, in operation, purge gas is circulated from an upper plenum **204** of the EFEM **114** into the EFEM chamber **114**C and via a first recirculation duct **128** is returned to the upper plenum. In another aspect, purge gas is circulated from the upper plenum **204** of the EFEM **114** into the EFEM chamber **114**C and via a second recirculation duct **214** is returned to the into the side storage pod **120** through a supply baffle **123**. Gas exits the side storage pod **120** back into the EFEM chamber **114**C. A small portion of the purge gas can be exhausted via exhaust conduit **132**. Replacement purge gas can be added (e.g., into the upper plenum) via purge gas supply **118**A.

Turning now to FIGS. **2** through **4**, details of the side storage pod **120** and how it couples to the EFEM body **114**B are described.

FIG. **2** is a side, cross-sectional, elevation view of the EFEM **114** including the side storage pod **120** coupled to a side wall of the EFEM body **114**B. FIG. **3** is a side, cross-sectional, elevation view of the side storage pod **120**. FIG. **4** depicts details of a supply baffle **123**.

In some embodiments, the side storage pod **120** is removably attached to the EFEM body **114**. The side storage pod **120** may be used to store substrates **202** under specific environmental conditions. For example, the side storage pod **120** may store the substrates **202** in the same environmental conditions as are being maintained in the EFEM chamber **114**C, except that they may be subjected to higher purge gas flow velocities. The side storage pod **120** may be fluidly coupled to (i.e., in fluid communication with) the EFEM chamber **114**C and may receive recirculated gas (e.g., purge gas) from the EFEM **114** (e.g., via recirculation duct **212** of the EFEM **114**). Accordingly, substrates **202** stored in the side storage pod **120** are exposed to the same environmental conditions as the EFEM **114**, but a different purge gas velocity.

In particular, the side storage pod **120** may include a lower circulation fan **205**B, chemical filter **220**B', particle filter **220**B", and a pod heater **222**B, which further enables substrates **202** stored in the side storage pod **120** to be constantly exposed to the same environmental conditions as in the EFEM **114** but higher flow, and, in some embodiments, further filtered and/or heated gas. Recirculated purge gas may be pushed from the upper plenum **204** into the EFEM chamber **114**C by an upper circulation fan **205**A located adjacent to the upper plenum **204**. In some embodiments, the gas flow through the side storage pod **120** is 150-200 cfm (4.25-5.67 cmm), or even 150-175 cfm (4.25-5.0 cmm). In some embodiments, new gas (e.g., purge gas) may additionally or alternatively be supplied to the upper plenum **204** via the purge gas supply **208**.

The side storage pod **120** can include and be adapted to receive one or more side storage containers **124** that include multiple storage shelves **203** each configured to hold a substrate **202** within the one or more side storage containers **124**. In some embodiments, the side storage pod **120** may receive one or more vertically-aligned side storage containers **124** within one or more side storage chambers **210** of the side storage pod **120**. The side storage containers **124** may include openings **126** that face the interior of the EFEM chamber **114**C to allow flow of purge gas toward the EFEM chamber **114**C. Note that recirculation ducts **128**, **214** include multiple passages as shown that allow the gas to flow around the base **216** of the EFEM robot **117**. Other numbers and locations of entry passages are possible. Thus, as indicated by the various gas flow arrows adjacent the base **216** of the EFEM robot **117**, a first portion of the exhaust gas may exit the EFEM **114** via exhaust conduit **132**, a second portion of the exhaust gas may be recirculated to the upper plenum **204** via the return duct **128** having a portion **213** formed within an access door **122** of the EFEM **114**, and yet a third portion of the exhaust gas may be recirculated back into the side storage pod **120** via the return duct **214** and pulled by fan **205**B.

An upper filter **220**A may be included in the purge gas flow generated by the fan **205**A. For example, the filter **220**A may be located proximate the upper plenum **204** so that the gas pushed by the fan **205**A passes through the filter **220**A. In some embodiments, the filter **220**A may be a chemical filter and/or a particle filter that filters one or more gasses that are outgassed by a substrate **202** in the side storage pod **120** after application of a fabrication process. The particle filter may be a fine filter sufficient to remove particles that would degrade the substrates.

In some embodiments, the filter **220**A is adapted to filter chlorine, bromine, and/or fluorine. In some embodiments, the filter 220A may filter base gasses, such as ammonia (NH_3), such as to less than or equal to 5.0 ppb. In some embodiments, the filter 220A may filter acidic gasses, such as fluorine (F), chlorine (Cl), bromine (Br), acetate (OAc), nitrogen dioxide (NO2), nitrate (NO_3), phosphate (PO_4), hydrogen fluoride (HF), and hydrochloric acid (HCl), for example, such as to equal to or less than 1.0 ppb. In some embodiments, the filter 220A may be an activated carbon filter. In other embodiments, the filter 220A may be a particulate filter or include a particulate filter. In some embodiments, the filter 220A may be any combination of the above.

A heater 222A may also be located in the gas flow generated by the fan 205A. The heater 222A may heat the purge gas to a predetermined temperature as the exhaust gas is recirculated into the EFEM chamber 114C. In some embodiments, the heat generated by the heater 222A may be used as a reactant and/or to change the relative humidity in the EFEM chamber 114C and/or the side storage pod 120. In some embodiments, the heater 222A may heat the purge gas in the EFEM chamber 114C to increase outgassing from substrates 202 located in the side storage pod 120. The heater 222A can heat the gas to 5° C. or more above ambient temperature external to the EFEM 114.

A diffuser 224 may also be located in the gas flow generated by the fan 205A. The diffuser 224 may include a plurality of openings and/or a porous material adapted to uniformly distribute the gas flow from the upper plenum 204 evenly across the EFEM 114. In some embodiments, the filter 220A, the heater 222A, and the diffuser 224 can be combined in one or more different combinations. In some embodiments, the filter 220A, the heater 222A, and the diffuser 224 can be disposed in a different order than shown in FIG. 2. For example, the diffuser 224 and the filter 220A positions can be exchanged; the heater 222A and the filter 220A can be exchanged; the diffuser 224 and the filter 220A can be used without the heater 222A; or the filter 220A can be used alone. Any practicable arrangement and combination of the filter 220A, the heater 222A, and/or the diffuser 224 may be used.

The chemical filter 220B' and the particle filter 220B" may be included in the gas flow generated by the fan 205B. For example, the filters 220B', 220B" may be located proximate a lower plenum 212 so that the purge gas pushed by the fan 205B passes through the chemical filter 220B' and particle filter 220B". In some embodiments, the filters 220B', 220B" may filter one or more gasses that are outgassed by a substrate 202 in the side storage pod 120 after application of a fabrication process.

In some embodiments, the filter 220B' is adapted to filter chlorine, bromine, and/or fluorine. In some embodiments, the filter 220B' may filter base gasses, such as ammonia (NH_3), such as to less than or equal to 5.0 ppb. In some embodiments, the filters 220B' may filter acidic gasses, such as fluorine (F), chlorine (Cl), bromine (Br), acetate (OAc), nitrogen dioxide (NO_2), nitrate (NO_3), phosphate (PO_4), hydrogen fluoride (HF), and hydrochloric acid (HCl), such as to equal to or less than 1.0 ppb. In some embodiments, the filters 220B' may include an activated carbon filter. In other embodiments, the filter 220B" may include various different particulate filter types or sizes.

A heater 222B may also be located in the gas flow generated by the fan 205B. The heater 222B may heat the gas to a predetermined temperature as the exhaust gas is recirculated into the side storage pod 120. In some embodiments, the heat generated by the heater 222B may be used as a reactant and/or to change the relative humidity in the side storage pod 120 and/or the EFEM chamber 114C. In some embodiments, the heater 222B may heat the gas in the side storage pod 120 to increase outgassing from substrates 202 located in the side storage pod 120. The heater may heat the purge gas flow to 5° C. or more above ambient temperature outside of the EFEM 114.

In some embodiments, a sensor 302 may be provided in the gas path through the side storage pod 120. The sensor 302 can be of any of the types of sensors described above with respect to environmental monitor 130. The sensor 302 can be in communication with a heater/fan controller 304. The sensor 302 can provide feedback information to the heater/fan controller 304 to help regulate a desired flow rate (e.g., at a highest flow rate while still maintaining laminar flow or a target flow rate) and/or a desired temperature (e.g., matching the temperature in the EFEM 114 as indicated by environmental monitor 130) or at a temperature suitable to cause an accelerated reaction on and disassociation of chemical components from the substrates. In some embodiments, the heater/fan controller 304 may be in communication with and/or under the control of controller 106.

In some embodiments, the side storage pod 120 may include one or more gas flow guides 306. Gas flow guides 306 may be positioned and shaped to direct gas through the side storage pod 120 efficiently without pooling or forming of substantial eddy currents. Gas flow guides 306 may be formed from plates or sheet metal coupled to, for example, corners of the internal spaces of the side storage pod 120 (or parts/channels of the EFEM 114) along the gas flow path indicated by the gas flow arrows.

In some embodiments, disposed between a container plenum 226 and the side storage container 124, is a supply baffle 123 positioned and sized with an appropriate arrangement of openings to uniformly distribute laminar gas flow substantially evenly over the substrates 202 within the side storage containers 124.

An example embodiment of a supply baffle 123 is shown in FIG. 4. In the illustrated example of a side storage pod 120, gas flows into the lower portion of the container plenum 226. Thus, the supply baffle 123, as shown in FIG. 4, include an array of openings 402 where a size dimension 404 of openings at the lower end of the supply baffle 123 is smaller than a size dimension 406 of openings at the upper end of the supply baffle 123. The size of the openings 402 may gradually increase from the lower end to the upper end of the supply baffle 123. The sizes of the openings are selected to compensate for gas entering the lower portion of the container plenums 226 by causing an even amount of gas to flow into the side storage containers 124 along the entire height of the side storage containers 124. In other words, the smaller openings located at the lower portion of the container plenum 226 restrict gas flow more than the larger openings at the top portion. In some embodiments, the openings 402 may range in size from approximately 1 mm to approximately 100 mm, or other embodiments, approximately 10 mm to approximately 50 mm. The array of openings 402 shown includes evenly spaced round openings 402 but any practicable shape openings and spacing may be used to provide substantially uniform flow velocity over the substrates (e.g., no more than 25% flow variation).

In some embodiments where the gas flows into the container plenums 226 at a different location (e.g., in the middle), the array of openings can be modified to compensate for the different location (e.g., smaller openings can be located in the middle with larger openings at the top and bottom).

By extending the return duct portion **213** through the access door **122**, the space occupied by the return duct **128** is kept minimal. As indicated above, the return duct portion **213** in the access door **122** may couple to the upper plenum **204** located on the top of the EFEM **114**. The fan **205**A may assist drawing the gas from the return duct portion **213** into the upper plenum **204**. The upper plenum **204** may include or be coupled to outlets that cause a laminar gas flow through the EFEM chamber **114**C.

Turning now to FIG. **5**, an example method **500** of operating an EFEM **114** according to some embodiments is depicted as a flow chart. The method **500** includes providing an EFEM having an upper plenum and an EFEM chamber in fluid communication with the upper plenum, as well as a side storage pod in fluid communication with the EFEM chamber (block **502**). The side storage pod includes a container plenum. Purge gas is flowed into the upper plenum **204** and then into the EFEM chamber (Block **504**). At least a portion of the purge gas in the EFEM chamber is then recirculated into a side storage container **124** located within the side storage pod **120** coupled to the EFEM **114** via the side storage pod plenum **212**. Gas is exhausted from the side storage container **124** back into the EFEM chamber **114**C (Block **506**). Meanwhile, a portion of the purge gas in the EFEM chamber **114**C is also recirculated into the return duct **128** and back to the upper plenum **204** (Block **508**). In some embodiments, a small portion of the purge gas from the EFEM chamber can be purged from the EFEM **114** via an exhaust conduit **132** (Block **510**). Optional diffusion, filtering, and heating of the purge gas may be performed at any stage of the method **500**.

The foregoing description discloses example embodiments of the disclosure. Modifications of the above-disclosed apparatus, systems, and methods which fall within the scope of the disclosure will be readily apparent to those of ordinary skill in the art. Accordingly, while the present disclosure has been disclosed in connection with example embodiments, it should be understood that other embodiments may fall within the scope of the disclosure, as defined by the claims.

What is claimed is:

1. A side storage pod, comprising:
- a first interior chamber;
- a first side storage container located in the first interior chamber, the first side storage container configured to receive one or more substrates from an equipment front end module chamber, the first side storage container including an opening configured to be adjacent to a first opening of the equipment front end module chamber;
- a first container plenum in fluid communication with the first side storage container; and
- a recirculated gas flow between the equipment front end module chamber and the first container plenum.

2. The side storage pod of claim **1**, further including a first supply baffle disposed between the first container plenum and the first side storage container.

3. The side storage pod of claim **2**, wherein the first supply baffle includes a plurality of openings configured to distribute the recirculated gas flow evenly though the first side storage container.

4. The side storage pod of claim **1**, wherein the recirculated gas flow is received from a pod plenum coupled to a return duct.

5. The side storage pod of claim **1**, further comprising:
- a second interior chamber;
- a second side storage container located in the second interior chamber, the second side storage container configured to receive one or more substrates from the equipment front end module chamber, the second side storage container including an opening configured to be adjacent to a second opening of the equipment front end module chamber; and
- a second container plenum in fluid communication with the second side storage container.

6. The side storage pod of claim **5**, further including a second supply baffle disposed between the second container plenum and the second side storage container wherein the second supply baffle includes a plurality of openings configured to distribute the recirculated gas flow evenly though the second side storage container.

7. The side storage pod of claim **1**, wherein the recirculated gas flow is drawn from at least one of the equipment front end module chamber of the first container plenum using a fan in the side storage pod.

8. An electronic device processing system, comprising:
- an equipment front end module including an equipment front end module chamber having one or more interface openings and an upper plenum in fluid communication with the equipment front end module chamber; and
- one or more side storage pods attached to a body of the equipment front end module, the one or more side storage pods each including:
  - a first interior chamber;
  - a first side storage container located in the first interior chamber, the first side storage container configured to receive one or more substrates from the equipment front end module chamber, the first side storage container including a first opening located adjacent to a first opening of the equipment front end module chamber;
  - a first container plenum in fluid communication with the first side storage container; and
  - a recirculation gas flow between the equipment front end module chamber directed to flow and the first container plenum.

9. The electronic device processing system of claim **8**, further comprising a heater located proximate to the first container plenum, the heater configured to heat gas flowing between the equipment front end module chamber and the first container plenum.

10. The electronic device processing system of claim **8**, further comprising a fan, the fan configured to recirculate gas between the first container plenum and the equipment front end module chamber.

11. The electronic device processing system of claim **8**, further including a first supply baffle disposed between the first container plenum and the first side storage container.

12. The electronic device processing system of claim **11**, wherein the first supply baffle includes a plurality of openings configured to distribute gas flow from the first container plenum substantially evenly throughout the first side storage container.

13. The electronic device processing system of claim **8**, wherein the recirculating gas flow is drawn from at least one of the equipment front end module chamber or the first container plenum by a fan in the one or more side storage pods.

14. The electronic device processing system of claim **8**, wherein the one or more side storage pods each further comprise:
- a second interior chamber;
- a second side storage container located in the second interior chamber, the second side storage container configured to receive one or more substrates from the

equipment front end module, the second side storage container including an opening configured to be adjacent to a second opening of the equipment front end module; and

a second container plenum in fluid communication with the second side storage container.

15. A method of operating an equipment front end module, comprising:

providing an equipment front end module having an upper plenum and an equipment front end module chamber in fluid communication with the upper plenum;

flowing purge gas from the upper plenum into the equipment front end module chamber;

recirculating some of the purge gas from the equipment front end module chamber into a side storage container of a side storage pod;

exhausting purge gas from the side storage container back into the equipment front end module chamber; and

recirculating some of the purge gas between the equipment front end module chamber and the upper plenum.

16. The method of claim **15** further comprising purging a portion of the purge gas from the equipment front end module chamber via an exhaust port.

17. The method of claim **15** comprising filtering chemicals from the purge gas using a chemical filter disposed in the side storage pod.

18. The method of claim **15** comprising heating the purge gas using a heater disposed in the side storage pod.

19. The method of claim **15** comprising filtering particles from the purge gas with a particulate filter disposed in the side storage pod.

20. The method of claim **15** wherein flowing purge gas between the equipment front end module chamber and the side storage container includes flowing gas between the equipment front end module chamber and a side storage plenum wherein the side storage plenum is in fluid communication with the side storage container.

21. The method of claim **20** wherein flowing purge gas from the equipment front end module chamber between the equipment front end module chamber and the side storage container further includes substantially evenly distributing the gas flow between the equipment front end module chamber and the side storage container using a supply baffle disposed between the side storage plenum and the side storage container.

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